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Importance of Protecting Spectrum used for Earth Observation

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Abstract

Radio frequencies are a finite and valuable natural resource facing increasing demand. This resource is essential for a wide range of applications, particularly those of which rely on Earth Observation (EO) satellites to deliver critical data for climate change monitoring, weather forecasting, disaster management, and other essential operational and scientific endeavours. This paper discusses the importance of the spectrum used for downlinking EO data using the 8025-8400 MHz frequency band (i.e., the X-band), emphasizing the need to protect it and the difficulties in doing so. It examines the current regulatory framework governing the X-band data downlink and the work related to World Radiocommunication Conference 2027 (WRC-27) agenda item 1.7 on the protection from the operation of International Mobile Telecommunications (IMT) systems, which are proposing to share this band. This paper explores the potential impacts of IMT on the EO user community, and advocates for collective efforts to protect the vital, critical spectrum.

Keywords: Earth Observation, IMT, X-band, WRC-27

Nomenclature

None

Acronyms/Abbreviations

1G	First Generation
2G	Second Generation
3G	Third Generation
4G	Fourth Generation
5G	Fifth Generation
6G	Sixth Generation
BR	Radiocommunication Bureau (of the ITU)
C-band	3700 – 4200 MHz
CSA	Canadian Space Agency
DTE	Direct-to-Earth
EESS	Earth-Exploration Satellite Service
EO	Earth Observation
FS	Fixed Service
FSS	Fixed Satellite Service
GEO	Group on Earth Observations
GPS	Global Positioning System
IMT	International Mobile Telecommunications

IoT	Internet of Things
ISL	Inter-Satellite Link
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union – Radiocommunications
MIFR	Master International Frequency Register
MS	Mobile Service
PCS	Personal Communications Service
RF	Radio Frequency
RR	Radio Regulations
SDG	Sustainable Development Goals
WP	Working Party (of an ITU Study Group)
WRC	World Radiocommunication Conference
X-Band	8025 – 8400 MHz (specifically the part of X-band which EO is concerned with)

1. Introduction

Earth Observation (EO) satellites have become essential tools for monitoring our planet. They deliver critical data on climate change, natural disasters, resource management, and national security. However, this critical technology faces a significant challenge: sharing the spectrum with mobile communications. The upcoming 2027 International Telecommunication Union (ITU) World Radiocommunication Conference (WRC-27) will review and assess proposals related to the potential identification of portions of the 8025-8400 MHz (space-to-Earth) frequency band (hereafter referred to as the X-band and currently used by many EO satellites), for International Mobile Telecommunications (IMT). The potential use of this type of mobile communications in this frequency band could have significant implications for the future of EO applications. This paper focuses on the importance of protecting the X-band for downlinking data from EO satellites operating in the Earth Exploration Satellite Service (EESS).

2. The International Telecommunication Union and World Radio Conferences

The ITU is a United Nations specialized agency that was founded in 1865 to help address the growing need for international cooperation in telegraph. Since then, and now with a membership of 194 Member States [1], the ITU has evolved. Its international Radiocommunication Regulations (RR) regulate the radio frequency (RF) spectrum, including the allocation of radio frequencies, conditions governing its use, and the registration of RF assignments. In addition, for space services, the ITU regulates the use of orbits. These regulations are described in the RR and are treaty-binding. Additionally, the ITU-R coordinates efforts to eliminate harmful interference between radio stations of different countries and to improve the use of RF spectrum for radiocommunication services and satellite orbits. As stated in Article 44 of the ITU Constitution, orbits and radio frequencies are limited natural resources and must be used rationally, efficiently, and equitably [2].

Typically, frequency allocations for new services need to be made in the ITU Radio Regulations (RR) before they can be used. Modifications, including revised or new allocations to the RR can only be made through a World Radio Conference which occurs approximately every four years. The agenda of each WRC is decided at the previous WRC. The time between the conferences is used to study issues and develop proposals to change the RR.

At the WRC in 2023 (WRC-23), it was decided to conduct sharing and compatibility studies for the potential introduction of IMT in the frequency bands 4400-4800 MHz, 7125-8400 MHz (or parts thereof), and 14.8-15.35 GHz. This issue is agenda item 1.7 for WRC-27. Leading up to WRC-27, the IMT communities, as well as the incumbent users of the spectrum under consideration, will study the potential impacts to and sharing of these frequency bands.

3. The 8025 – 8400 MHz Frequency Band

3.1 Earth Exploration Satellite Service in the X-Band

The X-band was first allocated to the EESS in the mid-1970s. With a wide allocation of 375 MHz, this frequency band is used by spacecraft to transmit large volumes of data collected by data intensive gathering missions (i.e. high-resolution synthetic aperture radars, optical sensors) that require downlink speeds greater than 100 Mbps. There are other frequency bands available for downlinking smaller volumes of data, however, the X-Band is best suited to and the most used band for downlinking high-capacity data associated with EO missions. There are over 248 satellite constellations registered in the ITU's Master International Frequency Register (MIFR) [3] and a significant number of ground stations throughout the world supporting spacecraft that downlink data in this band.

Despite congestion, the X-band continues to be used by many older and newer EO satellite systems alike. The X-band is robust, not highly susceptible to atmospheric losses, cost efficient compared to other frequency bands that could potentially be used for downlinking EO data, and is allocated to EESS on a primary basis. Spectrum is allocated by the ITU on either a 'primary' or 'secondary' basis. Generally, spectrum allocated as 'secondary' shall not cause harmful interference to services allocated as 'primary' nor claim protection from harmful interference from services having a 'primary' allocation. Of all the frequencies allocated to services between 0 kHz and 275 GHz in the International Table of Frequency Allocations [4], there is a total of over 6 GHz of bandwidth allocated to EESS for data downlinking. However, not all this spectrum is allocated on a primary basis. Aside from the X-band allocation, the next largest amount of bandwidth for downlinking EO data is a primary allocation of 1.5 GHz of spectrum allocated to EESS (space-to-Earth) in the frequency range 25.5-27 GHz. These frequencies are used by the space science community, with increasing adoption of the 25.5-27 GHz frequency band to meet growing data demands by the scientific community and others.

3.2 Earth Observation Data and Applications

Information about climate, climate change, weather, precipitation, pollution, or disasters is an important everyday issue for the global community. EO satellites play a vital role in understanding and managing our planet, providing a wealth of information. EO activities provide information that is required for daily weather forecast and prediction, studies of climate change, the protection of the environment, economic development (transport, energy, agriculture, building construction, etc.), national security, and for the provision of timely data for communities at risk of natural disasters to improve mitigation and response efforts. Here are some examples:

- Climate Monitoring: EO satellites track changes in sea level, ice cover and greenhouse gas concentrations, while providing crucial data for understanding and mitigating climate change. In turn, this information is used for climate, weather and water monitoring, prediction and warnings, natural disaster risk reduction, support of disaster-relief operations and for planning preventive measures for adapting to and mitigating negative effects of climate change.

- Disaster Response: EO satellites provide real-time imagery after natural disasters such as hurricanes, floods and wildfires, helping to assess damage and guide relief efforts. The Group on Earth Observations (GEO) emphasizes the importance of "Earth Intelligence," which leverages EO data for improving climate information and disaster risk knowledge [5]. Thousands of natural disasters worldwide in the last few years have taken the lives of many people and produced economic losses estimated at over 1.4 trillion dollars (US) between 2010 - 2019 [6]. Most of the losses were caused by weather, climate, and water-related hazards, such as droughts, floods, severe storms and tropical cyclones.

- Resource Management: EO data helps monitor forests, water resources, and agricultural lands, enabling sustainable management practices.

- National Security: EO satellites provide critical intelligence for national defence and security applications such as maritime domain awareness through vessel detection.

In addition to these functions, "EO data is essential for assessing the overall state of the planet, including progress towards achieving the Sustainable Development Goals (SDGs) set out by the United Nations" [7]. With EO data volumes projected to reach two exabytes by 2032, the importance of this technology continues to grow [8]. It is, however, difficult to quantify tangible benefits to society because there are no simple methods to measure loss of life and damage to the environment into economic equivalents; moreover, some benefits can only be evaluated or realised over very long periods of time. EO satellites need reliable frequency bands to download their data since all countries of the world derive important benefits from the data collected.

3.3 The Evolving Role of X-Band in Earth Observation Data Downlink

Historically, space agencies and government entities used the X-band for downloading data from space science service satellite missions. Between 2006 and 2015, governments were responsible for 85% of the 194 EO satellites launched by public and commercial entities [9]. Typically, ground stations that downloaded this EO data in the X-band had antennas that were large in diameter (>10 metres), more expensive to build compared to smaller antennas and quite often, located at higher latitudes to maximize the number of daily contacts with polar orbiting satellites.

More recently, commercial entities are now also operating EO constellations. One study [10] projects that 2850 commercial EO satellites will be built and launched between 2022 and 2032. This shift in EO operations is driven by two complementary trends. The miniaturization of sensors and the rise of small satellites have increased accessibility, allowing more nations and businesses to contribute to publicly available EO data. Meanwhile, larger, more advanced satellites are being developed to meet the demand for high-resolution and continuous data transmission. As the volume of EO data continues to grow, there will be an increasing demand for the X-band to efficiently downlink large amounts of data. Commercial entities are building more ground stations throughout the world, with smaller antennas, allowing for faster access to data. These stations are strategically positioned near internet backbones to ensure timely and reliable data delivery for scientific, environmental, commercial, and security applications. Together, these trends are shaping the future of satellite EO and its role in addressing global challenges.

4. The Evolution of IMT

4.1 IMT Progression

Personal Communications Service (PCS) started in the 1980s with the introduction of first generation (1G) cellular networks [11] (see Table 1). This service allowed users to make voice calls on the move, operating in the 800 MHz – 900 MHz frequency range. Texting and Multimedia Messaging Services were introduced in the 1990s with the second generation (2G) networks, using frequencies in the 1.8 GHz range and providing a data throughput of 64 kbps. Into the 2000s, the third generation (3G) networks were introduced, with throughputs of up 2 Mbps allowing for mobile internet access and Global Positioning System (GPS) on mobile devices operating in the 1.6 – 2 GHz frequency range. The fourth generation (4G) networks introduced video and wearable devices in the 2010s, operating Mobile Service (MS) allocations in the 2 – 3 GHz frequency range, with throughputs of up to 1 Gbps. The 2020s introduced the fifth generation (5G) networks, which further expanded capabilities by supporting high-definition video, wearable devices, and the "Internet of Things' (IoT). These applications are being designed to operate in a variety of allocations throughout the 3 – 30 GHz frequency ranges, delivering throughputs of up to 10 Gbps. As mobile technology continues to advance, frequency allocations and network capacity remain critical to supporting increasing demands for faster speeds, lower latency, and enhanced connectivity.

Table 1. IMT Systems Evolution

IMT Systems	Start of Deployment	Type of Service	Throughput	Frequencies
1G	1980s	Voice calling	N/A (analog)	800 MHz
2G	1990s	+ Texting	64 kbps	+ 1.8 GHz
3G	2000s	+ Internet, GPS	2 Mbps	+ 1.6 GHz to 2 GHz
4G	2010s	+ Video, Wearable devices	0.1 to 1 Gbps	+ 2 GHz to 8 GHz
5G	2020s	+ Ultra HD, 3D video, IoT, wearables	1 to 10 Gbps	+ 3 GHz to 30 GHz
6G	2030s	Fully digital connected world	>10 Gbps	+ 30 GHz to 300 GHz

4.2 Allocating More Spectrum

The IMT community is driven by the increasing demand for mobile broadband connectivity and the need for additional spectrum to support the deployment of 5G and future sixth generation (6G) technologies. Their vision for 6G (known as IMT-2030) includes higher data rates, lower latency, and support for a wider range of applications, including autonomous vehicles, 'smart' cities, and IoT [12]. This vision requires the need for additional spectrum, leading to the IMT community's growing interest in the X-band. Thus, the IMT proponents continue to advocate for more frequency allocations on a global basis, if possible, for their systems. The IMT proponents plan and design applications for frequency allocations that may or may not yet have been identified in the Radio Regulations. Some of these frequency allocations were identified throughout the years, through the ITU and WRC processes. Figure 1 shows all the IMT frequency band identifications categorized by ITU regions up to and including WRC-23.

The ITU divides the world into three regions. Region 1 comprises Europe, Africa, Russia and former Soviet Union states and parts of the middle East. Region 2 comprises the Americas, Greenland, and some Pacific Islands. Region 3 comprises Asia, excluding the former Soviet Union states and Oceania. As in any marketplace, economies-of-scale play an important role in technology adoption. Having harmonized spectrum identifications across all ITU regions is critical for the mass production and affordability of IMT devices, ensuring global interoperability and efficient network deployment.

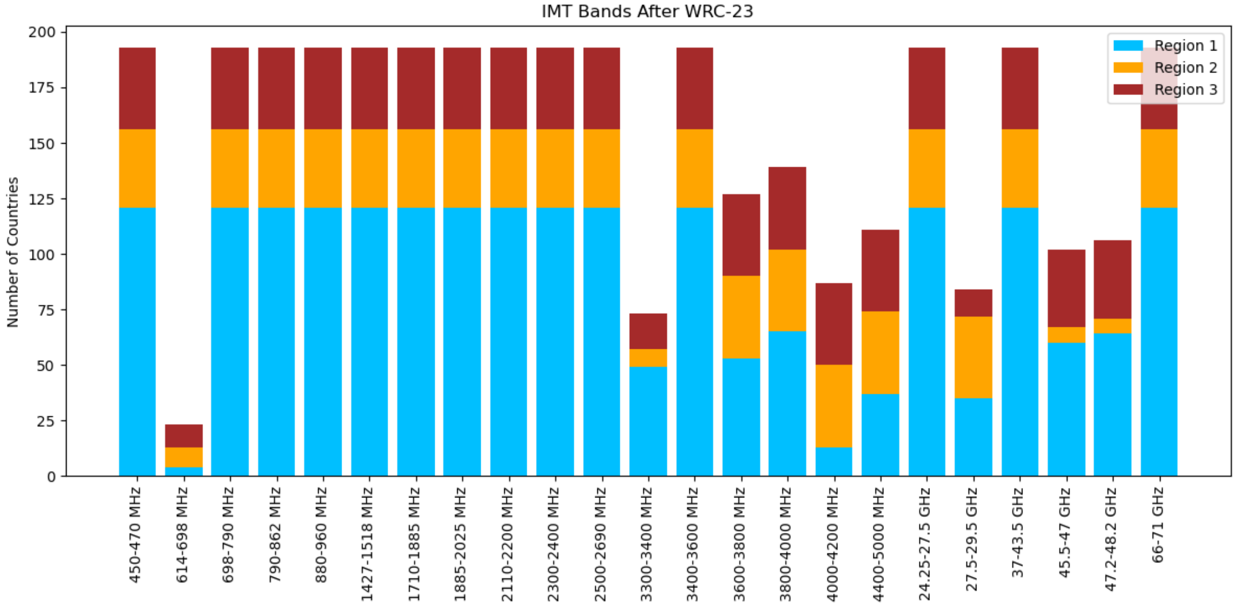

Figure 1. IMT Frequency Allocations; Image reproduced from source: ITU/BR [13]

It is understandable that a significant amount of spectrum includes identifications for the use of IMT. The world has become a more connected society and demand for mobile data has increased exponentially. Since the 1990s, WRCs have identified more than 21 GHz of bandwidth for IMT use, as shown in Figure 1, but not all this spectrum is currently being used for IMT. Despite this, IMT proponents continue to advocate for additional spectrum identifications at WRC-27.

5. World Radio Conference 2027 Agenda Item 1.7

Within the ITU-R, proponents of IMT are in the process of evaluating the introduction of IMT applications into the X-band and managing the potential impact that such use of the spectrum would have on incumbent and future EESS services. WRC-23 Resolution 256 [14] establishes the framework for the technical, operational, and regulatory issues pertaining to the use of IMT in the X-band. The resolution has a stated objective that any outcomes or decisions based on the studies protect incumbent services allocated on a primary basis without imposing additional regulatory or technical constraints.

The work of the ITU-R is divided among different study groups, each focusing on their area of expertise. The group that leads IMT work at the ITU-R is responsible for addressing this issue and presenting the results of its studies at WRC-27. However, since the implementation of IMT in any existing band may impact existing services, the incumbent services are naturally concerned and are involved in the work of the lead group. The ITU Working Party (WP) that is the lead group is WP 5D, “IMT Systems”. This group meets approximately three times a year to discuss and progress the work of WRC-27 agenda item 1.7, as well as other WRC-27 agenda items and tasks for which it is responsible. As the meetings work to finalize the characteristics used in sharing studies, preliminary studies have been submitted, and those results have shown that large separation distances will be needed between the stations of these two services. This work will progress until WRC-27, scheduled to start in October 2027.

6. The Impact of IMT in Satellite Frequency Bands

6.1 Sharing between mobile services and satellite services

Satellite services can share spectrum with fixed terrestrial services. Fixed Service (FS) systems use either point-to-point or point-to-multi-point links between terrestrial stations. These types of systems typically can co-exist with satellite services because both the terrestrial stations and earth stations (which are used for satellite services) have stable locations and fixed radiocommunication links allowing for the possibility of frequency coordination. However, the sharing environment between land mobile systems (i.e., an application such as IMT with a high deployment density of stations) and satellite systems is more challenging. There are allocations where mobile and satellite services co-exist, but they do not operate in the same geographical areas. The spectrum requirements of traditional land-mobile systems (i.e. non-IMT applications) were also not broadband enabled at the time.

Advancements in technology have resulted in higher power spectral densities and increased spectrum. Therefore, IMT proponents are looking to expand their spectrum into adjacent bands and new bands alike. However, unlike fixed terrestrial systems, land-mobile base stations use sector antennas that cover wide areas. Thus, if there are any receiving earth stations within that coverage area, the high-powered signals from the land-mobile base stations can interfere with the earth station’s receiving antennas. The interference is amplified with a high density of deployment, which is typical of IMT systems. These systems cannot share effectively without extraordinary measures. For co-existence, either the power densities of the land-mobile base stations need to be limited to prevent interference with receiving earth stations or there needs to be sufficient distance (i.e., an exclusion zone) between base stations and earth stations.

6.2 Case in Point: C-band in Canada

Since the 1970s, the 3500 – 4200 MHz frequency band was used for Fixed-Satellite Service (FSS) telecommunications. In Canada, the 3700 – 4200 MHz (i.e., C-band) frequency band was used by domestic Fixed Satellite Service (FSS) to provide downlink (space-to-Earth direction) applications such as telephony, broadcasting, and data transmission across the country. The 3500 – 3700 MHz frequency band was referred to as the “extended C-band” and was used predominantly for international (i.e., oversea) satellite links. Towards the late 1990s, the use of the C-band FSS satellites in Canada was not as prevalent, as satellite operators were opting to use higher frequency bands. The C-band, however, remains in use today by the FSS, although with restrictions.

In the 3500 – 4200 MHz frequency band, the FS also operates as an equal co-primary service to the FSS in the band. At the time, the MS could also operate alongside these two services, but only in the 3650 – 3700 MHz frequency band [15]. By 2014, a condition restricted fixed-satellite earth stations operating in the 3650 – 3700 MHz, limiting their locations to not constrain the implementation of fixed wireless access systems [16]. By 2018, a primary allocation to the MS was made in the 3500 – 3650 MHz frequency band, with the same restriction placed on the FSS [17].

With growing IMT spectrum demand in Canada, the MS was allocated additional spectrum. In August 2020, the Canadian spectrum regulator consulted the public on the use of the 3650 – 4200 MHz frequency band. Due to demands on next generation technologies, such as 5G, the regulator repurposed the lower part of the 3700 – 4200 MHz frequency band. The MS allocation was expanded to the 3700 – 4000 MHz frequency band and the FSS was removed [18]. As of March 31, 2025, new FSS ground stations are no longer licensed in the frequency band 3700 – 4000 MHz, except for in satellite-dependent areas and specific identified gateway locations. Any existing earth station operations in non-satellite-dependent areas in the frequency band 3700 – 4000 MHz now operate on a non-protection basis. This decision by the regulator was driven by the increasing need for more advanced IMT systems, the declining use of FSS systems in the band, and the impracticality of coexistence between the stations of these two services in close proximity.

6.3 Future Considerations: Inter-Satellite Links in EO Missions

Future EO missions may increasingly use inter-satellite links (ISLs) through satellite constellations to relay data. ISLs can enhance coverage by providing near-global access, reduce latency, and offer alternative pathways when ground stations are unavailable due to outages or adverse weather conditions.

However, Direct-to-Earth (DTE) X-band downlinks remain essential because they provide independence from ISL dependencies. Ground stations with high-gain antennas offer a reliable and cost-effective method for high-capacity data transmission. DTE links are also crucial for real-time monitoring, mission control, and resolving anomalies when immediate access to data is required. While ISLs can complement data relay, they cannot entirely replace the role of DTE X-band transmissions. A direct link to Earth ensures secure, uninterrupted, and independent access to mission critical EO data, making it a fundamental component of future satellite operations.

7. Conclusion and Call to Action

The X-band (8025–8400 MHz) is crucial for EO satellites, delivering critical data for climate monitoring, disaster response, resource management, and national security—applications central to addressing global challenges like those in the United Nations' Sustainable Development Goals. Proposals at the WRC-27 to identify parts of this spectrum to IMT require comprehensive analysis and studies by both the EO and IMT communities in order not to disrupt EO operations. We invite administrations and agencies to take an active role in this process and contribute expertise through comprehensive studies and technical analyses to inform balanced decisions at WRC-27. By evaluating coexistence options and the socioeconomic value of EO data, these efforts will ensure decisions reflect the needs of all spectrum users.

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References

[1] ITU. (2025). *About International Telecommunication Union (ITU)*. https://www.itu.int/en/about/Pages/default.aspx
[2] ITU. (2023). *Collection of the basic texts adopted by the Plenipotentiary Conference*. https://search.itu.int/history/HistoryDigitalCollectionDocLibrary/5.23.61.en.100.pdf
[3] ITU. (2025). *ITU Space Explorer*. Retrieved February 28, 2025, from, https://www.itu.int/itu-r/space/apps/public/spaceexplorer/networks-explorer
[4] ITU. (2024) *Radio Regulations Articles Edition of 2024*. https://www.itu.int/hub/publication/r-reg-rr-2024/
[5] Group on Earth Observation. (2023). *GEO Post 2025 Strategy*. https://earthobservations.org/storage/app/media/documents/Key-Documents/GEO%20Post%202025%20Strategy%20Full%20Document.pdf
[6] World Meteorological Organization. (2023) Economic costs of weather-related disasters soars but early warnings save lives. https://wmo.int/news/media-centre/economic-costs-of-weather-related-disasters-soars-early-warnings-save-lives
[7] ITU. (2023). *Science services: Observing our planet and understanding climate change*. https://www.itu.int/hub/2023/10/science-services-observing-our-planet-and-understanding-climate-change/
[8] World Economic Forum. (2024). *Charting the Future of Earth Observation: Technology Innovation for Climate Intelligence White Paper, September 2024*. https://www3.weforum.org/docs/WEF_Charting_the_Future_of_Earth_Observation_2024.pdf
[9] *Satellite-Based Earth Observation Market Prospects to 2025- The Only Source for Comprehensive Industry Analysis and Forecasts in the Fast-Changing Earth Observation Sector* (9th ed.). (2016). Euroconsult.
[10] *Satellites to Be Built & Launched - A Complete Analysis and 10-Year Forecast of the Satellite Manufacturing and Launch Service Markets* (26th ed.). (2024). Euroconsult.
[11] Government of Canada. (2024). *5G Explained (DDN2-A21)*. https://www.csps-efpc.gc.ca/tools/articles/5g-explained-eng.aspx
[12] U. Löwenstein. (2024, December 11). *ITU-R Update: IMT-2030 (6G)* [Presentation]. UNIDIR's Technology and Security Seminar on 6G, Geneva, Switzerland. https://unidir.org/event/technology-and-security-seminar-on-6g-preparing-for-the-next-generation-of-connectivity/

[13] K. Bogens. (2024, December 2-6). *Trends in broadband radio technologies* [Presentation]. ITU World Radiocommunication Seminar, Geneva, Switzerland. https://www.itu.int/en/ITU-R/seminars/wrs/Documents/2024/Presentations/17-Broadband_trends_WRS24_K_Bogens.pdf
[14] ITU. (2023). *Resolution 256 (WRC-23) Sharing and compatibility studies and development of technical conditions for the use of International Mobile Telecommunications (IMT) in the frequency bands 4 400-4 800 MHz, 7 125-8 400 MHz (or parts thereof), and 14.8-15.35 GHz for the terrestrial component of IMT.* https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A0000110007PDFE.pdf
[15] Industry Canada. (2009). *Spectrum Utilization Policy, Technical and Licensing Requirements for Wireless Broadband Services (WBS) in the Band 3650-3700 MHz.* https://ised-isde.canada.ca/site/spectrum-management-telecommunications/sites/default/files/attachments/2022/sp3650-ps3650-eng.pdf
[16] Industry Canada. (2014). *Canadian Table of Frequency Allocations (2014 Edition)*. https://publications.gc.ca/collections/collection_2022/isde-ised/Co23-1-2014-eng.pdf
[17] Government of Canada. (2018). *Canadian table of frequency allocations (2018 Edition)*. https://publications.gc.ca/site/eng/9.856955/publication.html
[18] Government of Canada. (2022). *Canadian table of frequency allocations (2022 Edition)*. https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/learn-more/key-documents/consultations/canadian-table-frequency-allocations-sf10759